APPLICATION FOR PATENT

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Title: Smart device and system for improved domestic use and saving of water

CROSS REFERENCE TO RELATED APPLICATIONS

The present invention claims priority from U.S. Provisional Patent Application No. 60/454,635, filed 17 March 2003, the contents of which are incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to water systems, and in particular to systems for efficient heating, delivery and use of water. More specifically, the present invention relates to smart delivery and control systems for hot and cold water in domestic use.

BACKGROUND OF THE INVENTION

Domestic water systems generally comprise separate hot and cold water piping, the hot water being heated in a hot water tank, both hot and cold water normally provided to a common mixed water delivery device (e.g. a faucet) in places such as baths, showers, and sinks. In normal use, the "turn-on" of such a mixed device by a consumer that wants water at a desired temperature includes the steps of:

a. waiting until the hot water arrives from the tank. This may take a while, in which time water is basically wasted. This waste is estimated to be on average about 10 liters (or more than 2 gallons) per turn-on;

b. adjusting the water temperature to a desired value in a process that includes trial (feeling the water temperature) and waiting until the water reaches that temperature; and

c. running the water even in cases when it is not needed, thus causing unnecessary

waste.

A person taking a shower typically soaps him/herself while the water is running, and the same occurs for example during manual dishwashing. A faucet may be turned off while the water is not actually in use, but the majority of consumers do not do so, in order not to go through the "turn on" process again. Clearly, if one could temporarily turn off the flow of water and resume it instantly at the desired temperature, significant water and power savings could be attained.

A (partial) solution to the problem of waiting for hot water upon "turn-on" exists in hotels (but not normally in private homes). This solution consists of a circulation system that uses a double hot water pipe: the hot water pipe turns around and eventually returns to the hot water tank. Within the circle there is a small, preferably rotary pump that constantly circulates the hot water. The faucets are located close to a short mixed water pipe section that delivers water from the hot and cold pipes. Since at the entrance to this mixed pipe the water is always hot, when the faucet is turned on, the hot water arrives quite quickly. The disadvantages of this solution include a more expensive infrastructure (additional pipe to return the hot water) and waste of energy (both from the rotary pump which operates 24 hours a day, and from to continual leakage of heat from the hot water pipe to the surrounding environment). Obviously, this method is too expensive and energy-wasteful to be routinely applied in private homes.

The methods used in prior art for domestic hot water processing and delivery result in water and energy losses. It is thus desirable to provide devices, systems and methods that reduce these losses.

SUMMARY OF THE INVENTION

The present invention discloses a smart water delivery device and system for improved domestic use and saving of water. Specifically, the invention discloses a smart water delivery device operative to provide water at a desired temperature while preventing the waste occurring during present water turn-on events, when water is run and wasted until it becomes warm enough for use. Advantageously, the present invention does not require any addition to the piping infrastructure in a home (house, apartment,

etc).

It is an object of the present invention to supply water to a domestic user at exactly a desired temperature.

It is another object of the present invention to supply water at the desired temperature without wasting cold water until the arrival of water at the desired temperature.

It is yet another object of the present invention to provide prior notice to the user when the water is insufficiently warm.

According to the present invention there is provided a system for providing a user with water at a desired temperature comprising: a piping system that includes a hot water pipe and a cold water pipe; a pump coupled to the piping system; and a water delivery device coupled to the piping system and to the pump and operative to allow circulation of water from the hot water pipe to the cold water pipe prior to delivery of water at a desired temperature to the user, whereby the circulation purges the hot water pipe of any cold water contained therewithin.

According to one feature of the system of the present invention, the operativeness to allow circulation of water from the hot water pipe to the cold water pipe prior to delivery of water at a desired temperature to the user is facilitated by a circulation mechanism.

According to another feature of the system of the present invention, the circulation mechanism is included in the water delivery device.

According to yet another feature of the system of the present invention, the circulation mechanism is externally attached to the water delivery device.

According to yet another feature of the system of the present invention, the water delivery device includes a hot water inlet coupled to the hot water pipe, a cold water inlet coupled to the cold water pipe, and a common outlet operative to receive hot and cold water flows from the hot and cold water inlets and to facilitate the water delivery.

According to yet another feature of the system of the present invention, the circulation mechanism further includes a hot water inlet valve and a cold water inlet valve respectively coupled to and operative to control water flow through the hot and cold water inlets, at least one temperature sensor operative to sense water temperature,

and a controller responsive to inputs from the at least one temperature sensor and operative to actuate the hot and cold water inlet valves and the pump to obtain the water circulation and delivery.

According to yet another feature of the system of the present invention, the system further comprises an input/output device configured to provide input parameters to the controller and to receive and display output indications from the controller.

According to the present invention there is provided a method for delivering to a user water at a desired temperature comprising the steps of: providing a piping system that includes a hot water pipe and a cold water pipe; providing a water delivery device coupled to the piping system and configured to allow internal circulation of water from the hot to the cold pipe, the water delivery device having at least one outlet; bringing the water temperature near the at least one outlet to the desired temperature by purging the hot water pipe of any water having a temperature lower than the desired temperature, the purging including transferring of the lower temperature water through the water delivery device to the cold pipe; and delivering water at the desired temperature to the user through the at least one outlet.

According to the present invention there is provided a water delivery device comprising: a hot water inlet coupled to a hot water pipe; a cold water inlet coupled to a cold water pipe; a first outlet operative to receive hot and cold water flows from the hot and cold water inlets and to facilitate water delivery to a user; and a circulation mechanism operative to allow circulation of water from the hot water pipe to the cold water pipe prior to delivery of water at a desired temperature to the user through the first outlet.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings, wherein:

FIG. 1 shows a preferred embodiment of a system for improved domestic use and saving of heated water according to the present invention: (a) general view of a system

with wireless communications; (b) details of the water tank/pump surroundings in (a); and (c) general view of a system with wired communications between each faucet and pump/sensors.

FIG. 2 shows details of a smart faucet according to the present invention that has a single outlet;

FIG. 3 shows details of a smart faucet according to the present invention that has two outlets;

FIG. 4 shows schematically the functional connection of control and sensing elements in a smart faucet according to the present invention;

FIG. 5 shows an alternative embodiment of a smart faucet according to the present invention, in which the circulation mechanism is separate from the faucet;

FIG. 6 shows details of an exemplary control panel for the smart faucet of the present invention;

FIG. 7 shows various configurations of a smart faucet with a single outlet: a) automatic outlet control, and b) automatic outlet proximity control.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention discloses a system and device for improved domestic use and saving of water. The system is operative to supply hot water at a desired temperature upon request. Preferably, the system uses a smart device with electronic sensing and control. In contrast with existing domestic systems, the system of the present invention uses the existing piping infrastructure, but ensures that the cold water present in a hot water pipe remains in the system instead of being wasted when a user opens a faucet and requires hot water. In a preferred embodiment, the smart device is a smart faucet, which facilitates the water saving and supplies water at a constant temperature, after adjustment by the user, thereby reducing and preventing the risk of scalding. The smart faucet may be made operative to stop the flow of water during soaping, and to resume the flow of water at the desired temperature immediately upon a new request. The smart faucet has a number of advantageous features: it can be integrated into "smart home" systems, it may be remotely controlled, it may retain information on water consumption, etc.

FIG. 1a shows a preferred embodiment of a system **100** of the present invention implemented in a housing unit (e.g. private home). System **100** supplies hot water from a central water heating device or hot water tank **102** to various water delivery devices **104.** Devices **104** deliver water preferably at a desired temperature to a user, and are simply referred to as "faucets" **104.** Thus, a faucet **104a** represents a shower faucet, a faucet **104b** represents a bathroom sink faucet, faucet **104c** represents a bath and faucet **104d** represents a kitchen faucet, all configured in general for both hot and cold water delivery. The hot water leaves the tank through a common hot water pipe **106**, and the cold water is input to the tank through a common cold water pipe **108**. Each faucet is connected to both hot water pipe **106** (or branches thereof) and to cold water pipe **108** (or branches thereof). A faucet may be further configured to provide water at a requested temperature using a circulation mechanism **202** (see FIG. 2) that ensures that any cold water in the hot water pipe is circulated internally (in a closed loop) and not dumped out of the system through the faucet, when the user requests hot water. The circulation is provided by a small pump **110** inserted in a loop that comprises the common hot and common cold water pipes. The pump may be any type of pump, for example a rotary pump. Advantageously, the faucet configuration allows a volume of cold water existing in the hot water pipe between the faucet and the water tank to be routed (or "flushed") into a cold water pipe that runs back to tank **102**. This routing occurs internally in the faucet, by a coordinated opening and closing of faucet inlet valves, as described in more detail with reference to FIG. 2. Preferably, the inlet valves are "smart" valves, responsive to signals generated by a microcontroller preferably incorporated in the circulation mechanism, the microcontroller coupled and responsive to at least one temperature sensor used for sensing the water temperature. FIG. 1a also shows three temperature sensors **120** located at various heights in water tank **102**. Sensors **120** can provide absolute temperature as well as a temperature gradient for the water in the tank. FIG. 1a also shows transceivers **130** (at the water tank) and **132** (on each smart faucet), which are used in a wireless communication configuration of the system to transfer commands and temperature information between each smart faucet and the water tank and/or pump. The wireless communication method is illustrated in more detail in the enlargement of the water tank and pump surroundings in FIG. 1b. Alternatively, the communication between each smart

faucet and the pump and sensors (or more generally "actuation and sensing elements") may occur by a hard wire connection **140**, shown in FIG. 1c. Alternatively yet, communication is provided between the smart valves.

A faucet comprising a microcontroller operative to control the actuation of at least two smart inlet valves (and optionally of an additional outlet valve) in response to temperature signals provided by the at least one temperature sensor is referred to herein as a "smart faucet". When the water near an outlet of the smart faucet gets to be hot enough, as sensed by the temperature sensor, the internal cold water routing stops, and the hot water, alone or mixed with cold water to a desired temperature are provided to the user.

Heating device or hot water tank **102** may be solar-powered by a solar panel **112**. Alternatively, the water in tank **102** may be heated by any known heating source, e.g. electrical, gas, oil, etc. System **100** further preferably comprises a one-way ("no-return") valve **114**, positioned preferably, but not necessarily, on a cold water main **116**. Valve **114** ensures that the cold water from the hot water pipe circulated by pump **110** through the faucet is not pumped back (out of the housing unit) into the external cold water supply.

FIGS. 2 and 3 show details of a basic embodiment of a smart faucet according to the present invention. In particular, faucet **104** includes, as mentioned, a circulation mechanism **202** that facilitates routing of cold water from a hot water pipe into a cold water pipe through the faucet. In FIGS. 2 and 3, the circulation mechanism is part of (internal to) the faucet. Faucet **104** further has a hot water inlet **204** that connects hot water pipe **106** to an internal hot water pipe section **208**, and a cold water inlet **206** that connects cold water pipe **108** to an internal cold water pipe section **210**. Pipe sections **208** and **210** meet at a common internal pipe section **212**, which, in the embodiment of FIG. 2, is further connected to a single faucet outlet **214** (which may provide to the user mixed hot and cold water at any required temperature). Alternatively, as shown in the embodiment of FIG. 3, the faucet may include two separate outlets **304** and **306**, for example an upper outlet for a shower head and a lower outlet for a bath. Separate outlets **304** and **306** may each provide mixed hot and cold water, and a choice between them may be made by a manual selector **308**. Alternatively, as shown in the embodiment of FIG. 5,

each outlet may have a smart valve (**312** and **314**) that may be controllable by an electronic controller (referred to hereinafter as "microcontroller") **232**, and a choice between them may therefore be made by the microcontroller.

Circulation mechanism **202** includes two inlet valves **220** and **222** coupled to, and operative to control water flow through inlets **204** and **206** respectively, and an optional outlet valve **224** coupled to and operative to control water flow through outlet **214**. In FIG. 3, the outlet valve, marked as **226** is coupled to a common internal pipe section **228** functionally identical with pipe section **212** and to the two separate outlets **304** and **306**. Preferably, the two inlet valves and the outlet valve in FIGS. 2, 3 are "smart" valves, operative to open and close water flows upon reception of appropriate commands from microcontroller **232**. Optionally, outlet valve **224** may be manual. Mechanism **202** further includes at least one temperature sensor **244** operative to sense water temperature and preferably located proximal to outlet valve **224**. Note that in general, sensor **244** may be located in other sections of smart faucet **104** and still provide some of the benefits of the present invention, i.e. sense a water temperature and provide inputs to the microcontroller that affect the circulation. The circulation mechanism may include additional optional temperature sensors such as a hot water inlet sensor **240** operative to sense the temperature of the water at inlet **204** and a cold water inlet sensor **242** operative to sense the temperature of the water at inlet **206**.

FIG. 4 shows schematically the functional connection of control and sensing elements in a smart faucet according to the present invention. Microcontroller **232** is coupled (by hard wire or wirelessly) to all smart valves (**220**, **222**, **310** and **312**) temperature sensors (**240**, **242**, **244**), and an input/output device **400**. In case of wireless communication, microcontroller **232** tranmits and receives communications through a transceiver **484** (**132** in FIG. 1). Alternatively yet, the communication between the microcontroller and the actuating elements may be by ultrasonic transmission through the water. Microcontroller **232** is preferably an application specific integrated circuit (ASIC) located inside the faucet (as part of the circulation mechanism). Alternatively, microcontroller **232** may be located separately from the faucet, for example in device **400**. Microcontroller **232** is operative to provide the control commands for the actuation of the smart valves and of pump **110**. Microcontroller **232** is also operative to receive

temperature inputs from all temperature sensors, as well as inputs from input/output device **400,** and, responsive to these inputs, to provide actuation signals as needed to the valves and to the pump. The operation of ASIC systems that receive inputs and sensed temperature and relay commands is well known in the art, for example in home appliances such as ovens, dishwashers, etc.

As mentioned, inlet valves **220** and **222** are preferably smart valves responsive to command signals generated by microcontroller **232** as a result of, for example, inputs from device **400.** Power to operate the faucet's electronic, sensing and mechanical elements is preferably provided by a self-contained power source such as a battery **250** located in on near the faucet. Battery **250** may be any battery, e.g. a lithium battery that is powerful enough to satisfy the power demands of sensing, transmission/reception, actuation and control. Alternatively, the faucet may be connected to the regular domestic power grid or to a small water powered generator (turbine) **464** that also charges the battery. Generator **464** is preferably located in the water stream close to the faucet outlet, and is activated every time that water runs through the outlet. Alternatively, generator **464** may be located anywhere in the faucet where running water activates the small turbine, thereby generating power.

In an alternative embodiment of a smart faucet according to the present invention shown in FIG. 5, the circulation mechanism is external to and separate from the faucet itself. FIG. 5 shows a circulation mechanism **350** operative to perform the internal water circulation described above, connected through a cold water pipe section **352** and a hot water pipe section **354** to appropriate cold and hot water inlets in a faucet **356.** Mechanism **350** is interposed between faucet **356** and the piping system, serving basically as a smart adapter. The advantage of such an adapter is that it allows retrofitting of existing systems, using existing (non-smart) water delivery devices. Adapter **350** comprises two smart inlet valves **360** and **362** connected respectively through an inlet end to external cold and hot water pipes **366** and **368,** and through an outlet end to pipe sections **352** and **354** respectively. Valves **360** and **362** are further connected to each other through an additional smart valve **364.** Smart valves **360, 362** and **364** are all coupled electronically to a microcontroller **370** operative to receive temperature inputs from a temperature sensor **372** coupled to the hot water pipe, and operative to actuate all

smart valves to perform internal water circulation. Similar to mechanism in FIG. 4, mechanism **350** may be powered by a power source in the form of a battery **374**, optionally backed by at least one water powered generator **G**. Alternatively, mechanism **350** may be powered solely by the battery or generator, or be connected to the regular power grid.

One of the major advantages of the communication system of the present invention that uses a microcontroller in each smart faucet is that any potential user may be provided with the information that one or more of the smart faucets are in use. Thus, if a potential user desires hot water at a predetermined temperature, he/she will be able to know beforehand if enough hot water is available (by, e.g., measurement of temperature in the water tank), and if someone else is using hot water. The microcontroller may even be configured to calculate a remaining hot water amount in the system, and to provide the potential user this information.

In operation, upon request by a user for cold water, the cold water inlet valve will open, while the hot water inlet valve will remain closed. Upon request for hot water at a desired temperature, the water temperature in the hot water tank (as determined by one or more sensors **120**) is compared to the temperature shown on the panel (see FIG. 4) by pushing for example a hot water button **408**. If the amount of hot water available in the tank is enough for a required use period (say a shower for 5 minutes), the internal circulation process is started in order to flush any cold water from the hot water pipe up to the outlet. The circulation stops (preferably automatically) once the water reaches the desired temperature at the relevant outlet. If there is not enough hot water in the system for the required use, no circulation is started.

To perform internal circulation, the inlet hot and cold water valves (**220** and **222**) are opened in a coordinated fashion following commands from the microcontroller, while the outlet valve remains closed. The hot and cold water "loop" is now operative to have water flow in it upon action of the pump. The microcontroller transmits an appropriate command to the pump to commence operation. As mentioned, the command transmission may occur by wired or wireless means, or by ultrasonic signals transmitted through the water itself. In the loop, hot water flows from the hot water tank through the hot pipe to the hot water inlet of the faucet, while cold water flows through the cold water inlet back

toward the hot water tank. When sensor **244** senses the desired water temperature at the outlet, a visual or audio signal is generated to indicate this to the user. Upon this indication, the pump action is stopped manually (by for example pushing button **408** again) or automatically (by programmed instructions to the microcontroller), the cold water flow reverses direction, outlet valve **224** is opened, and the user receives water at the desired temperature. Note that if only water from the hot pipe is desired, the cold water inlet may be closed for the desired time period. Conversely, if only cold water is desired, the hot water inlet may be closed for the desired time period. The opening and closing of some or all of the valves (for example only the two inlet valves, or both inlet and outlet valves) and the temperature sensing are coordinated by the microcontroller.

FIG. 6 shows an embodiment of an exemplary input/output device **400** for the smart faucet of the present invention. Preferably, device **400** is in the form of a panel and will be referred to henceforth as a "control panel". Control panels of this type are well known in the art, for example in home appliances. The entire panel or parts thereof may be incorporated physically in the faucet. Alternatively, the entire panel or parts thereof may be located remotely from the faucet, for example on a wall next to the faucet. In a basic embodiment of a minimum panel configuration, the panel preferably includes a temperature readout **402,** hot and cold water selection buttons **406** and **408** for selecting either hot or cold water. Optionally, the panel may include a variety of other elements. For example, the panel may include a function selection mechanism **410** for selecting between different functions such as "temperature", "time", "flow", etc. Each function selected may be indicated by appropriate indicators: **422** for a temperature selection indicator, **432** for a time selection indicator and **444** for a water flow strength indicator. "Up" and "Down" buttons **440** and **442** are used for changing up and down (setting) the value of a chosen function. The panel may optionally further include a timer **430** for setting a desired water use time, a "time" indicator **432**, memory means **434** for storing set temperatures and/or times, and outlet selection buttons **452** and **454** for selecting one of two outlets.

If cold water is desired, pressing button **406** opens the cold water inlet valve. If hot water is desired at a set temperature chosen by function selection mechanism **410,** pressing button **408** opens both hot and cold water inlet valves and actuates the pump

while closing the outlet valve, thereby purging the hot water pipe of any cold water. This actuation is in response for an appropriate code sent by the microcontroller to each actuated element. Once hot water reaches the faucet and the right temperature is sensed by sensor **244** and indicated by readout **402** or by an optional "Ready" lamp **450,** the pump (i.e. the circulation) is stopped. This circulation stop is preferably automatic. An additional push on button **408** opens the outlet valve, providing the required hot water.

A constant desired temperature may be kept by a close-loop control involving the temperature sensor, microcontroller and both inlet valves. If the hot water supply decreases (e.g. if the temperature of the water in the hot water tank decreases), the close-loop control may change the ratio of hot/cold water supplied at the outlet by controlling for example the opening times of each inlet valve. In the case in which the faucet includes two outlets with electronic selection, the desired valve will be selected according to the button pressed. The desired temperature will be maintained by constant regulation of the inflow (inlet) and outflow (outlet) valves. To the extent the water coming from the tank becomes cold, a warning will be given and the water will be turned off automatically. To the extent that during or after the waiting time, the user wishes to increase or decrease the desired water temperature, he may do so by pressing the "Arrow Up" or "Arrow Down" buttons while the "Temperature" light is on. A timer (using the timer function) may be set to determine both usage times and breaks between uses (e.g. for soaping).

FIG. 7a shows a sink faucet **104'** having an integral control panel **400.** FIG. 7b shows a similar faucet **104"** that incorporates a control panel **400** and a proximity mechanism **502** that is used to actuate the water flow. Proximity mechanisms are known, but their incorporation in smart faucets as disclosed herein is new and inventive. In a proximity actuated faucet, the mechanism actuates the faucet outlet and water is supplied at the desired temperature. When the water flow stops, the pump driven circulation is automatically started so that water at the desired temperature is always available. Optionally, a delay may be programmed into the smart faucet between proximity actuation and water supply, during which time the circulation is actuated, bringing the water to a predetermined desired temperature.

Water flow (pressure) may be controlled by setting function selecting mechanism **410** to "flow" and using Up and Down buttons **440** and **442.** A "default" water flow or

pressure may be set at 50% (or any other percentage) of maximum flow.

If the faucet is of the type that includes memories, there will be one or more programmable memories in memory means **432**. Each such memory may store variables that include temperature, water use time, break time, wait time, water force, etc. A long press on the "Memory" button may enter into the selected memory the temperature, water force and time selected. A short press on any of the "Memory" buttons selects the appropriate value(s) from the memory.

While the invention has been described with respect to a limited number of embodiments, it will be appreciated that many variations, modifications and other applications of the invention may be made.